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Statement of inventorship and of right to grant of a patent

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	GBP13232B
2.	Patent application number *(if you know it)*	0016816.1
3.	Full name of the or of each applicant	Seiko Epson Corporation
4.	Title of the invention	OELD Compensated Pixel Driver Circuits
5.	State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent	By virtue of employment
6.	How many, if any, additional Patents Forms 7/77 are attached to this form? *(see note (c))*	
7.		I/We believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to.

Signature: Marks & Clerk Keygon

Date: 1st May 2001

8.	Name and daytime telephone number of person to contact in the United Kingdom	C M Sturt 020 7242 5974

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50135 MDC81

Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

Simon TAM
c/o Epson Cambridge Laboratory
8c Kings Parade
Cambridge CB2 1SJ

Patents ADP number *(if you know it)*: 7791128001

Patents ADP number *(if you know it)*:

Patents ADP number *(if you know it)*:

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THE PATENT OFFICE
07 JUL 2000
LONDON

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Request for grant of a patent

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1.	Your reference	GBP13232B 10JUL00 E551429-3 D00528 P01/7700 0.00-0016816.1
2.	Patent application number *(The Patent Office will fill in this part)* 07 JUL 2000	**0016816.1**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Seiko Epson Corporation 4-1, Nishishinjuku 2-chome, Shinjuku-ku, Tokyo 163-0811 Japan
	Patents ADP number *(if you know it)*	7123310C3
	If the applicant is a corporate body, give the country/state of its incorporation	Tokyo, Japan
4.	Title of the invention	ORGANIC ELECTROLUMINESCENT DEVICE COMPENSATED PIXEL DRIVE CIRCUIT
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Miller Sturt Kenyon 9 John Street London WC1N 2ES United Kingdom
	Patents ADP number *(if you know it)*	07395486001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country: ~~GB~~ — Priority application number *(if you know it)*: ~~0007879.0~~ — Date of filing *(day / month / year)*: ~~31/03/00~~ NO 23/4/01 1/77 30/4/01
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application — Date of filing *(day / month / year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Continuation sheets of this form	
Description	8
Claim*(s)*	3
Abstract	1
Drawing*(s)*	2 + 2 SW

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Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature: Mille Sturt Kenyon

Date: 7th July 2000

12. Name and daytime telephone number of person to contact in the United Kingdom: C M Sturt 020 7242 5974

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Organic ElectroLuminescent Device

Compensated Pixel Driver Circuit

The present invention relates to an organic electroluminescent device and particularly to a compensated pixel driver circuit thereof.

An organic electro-luminescent device (OELD) consists of a light emitting polymer (LEP) layer sandwiched between an anode layer and a cathode layer. Electrically, this device operates like a diode. Optically, it emits light when forward biased and the intensity of the emission increases with the forward bias current. It is possible to construct a display panel with a matrix of OELDs fabricated on a transparent substrate and with one of the electrode layers being transparent. One can also integrate the driving circuit on the same panel by using low temperature polysilicon thin film transistor (TFT) technology.

In a basic analog driving scheme for an active matrix OELD display, a minimum of two transistors are required per pixel (Figure 1): T_1 is for addressing the pixel and T_2 is for converting the data voltage signal into current which drives the OELD at a designated brightness. The data signal is stored by the storage capacitor $C_{storage}$ when the pixel is not addressed. Although p-channel TFTs are shown in the figures, the same principle can also be applied for a circuit with n-channel TFTs.

There are problems associated with TFT analog circuits and OELDs do not act like perfect diodes. The LEP material does, however, have relatively uniform characteristics. Due to the nature of the TFT fabrication technique, spatial variation of the TFT characteristics exists over the entire panel. One of the most important considerations in a TFT analog circuit is the variation of threshold voltage, ΔV_T, from device to device. The effect of such variation in an OELD display, exacerbated by the non perfect diode behaviour, is the non-uniform pixel

brightness over the display panel, which seriously affects the image quality. Therefore, a built-in compensation circuit is required.

A simple threshold voltage variation compensation, current driven, circuit has been proposed. The current driven circuit, also known as the current programmed threshold voltage compensation circuit is illustrated in figure 2. In this circuit, T_1 is for addressing the pixel. T_2 operates as an analog current control to provide the driving current. T_3 connects between the drain and gate of T_2 and toggles T_2 to be either a diode or in saturation. T_4 acts as a switch. Either T_1 or T_4 can be ON at any one time. Initially, T_1 and T_3 are OFF, and T_4 is ON. When T_4 is OFF, T_1 and T_3 are ON, and a current of known value is allowed to flow into the OELD, through T_2. This is the programming stage because the threshold voltage of T_2 is measured with T_2 operating as a diode (with T_3 turned ON) while the programming current is allowed to flow through T_1, through T_2 and into the OELD. T_3 shorts the drain and gate of T_2 and turns T_2 in to a diode. The detected threshold voltage of T_2 is stored by the capacitor C_1 connected between the gate and source terminals of T_2 when T_3 and T_1 are switched OFF. Then T_4 is turned ON, the current is now provided by V_{DD}. If the slope of the output characteristics were flat, the reproduced current would be the same as the programmed current for any threshold voltage of T_2 detected. By turning ON T_4, the drain-source voltage of T_2 is pulled up, so a flat output characteristic will keep the reproduced current the same as the programmed current. Note that ΔV_{T2} shown in figure 2 is imaginary, not real.

A constant current is provided, in theory, during the active programming stage, which is t_2 to t_5 in the timing diagram shown in figure 2. The reproduction stage starts at t_6.

The circuit of figure 2 is advantageous but there is an on-going desire to reduce power consumption. In particular, implementation of the current-source in the circuit of figure 2

requires a bias voltage (V_{BIAS}) in addition to the supply voltage (V_{DD}). Although the supply voltage (V_{DD}) could be increased to cover the required bias voltage (V_{BIAS}) – which would have the advantage of reducing the component count, there is still an overall increase in system power consumption to program with any value of data current (I_{DAT}).

According to a first aspect of the present invention there is provided a compensated pixel driver circuit for an organic electroluminescent device, the circuit comprising; a transistor connected so as operatively to control the current supplied to the electroluminescent device, a capacitor connected for storing an operating voltage of the transistor during a programming stage, a first switching means connected so as to establish when operative a current path through the transistor during the programming stage, and a second switching means connected so as to establish when operative a current path through the transistor and the electroluminescent device during a reproduction stage, wherein the first switching means is connected such that the current path during the programming stage does not pass through the electroluminescent device.

According to a second aspect of the present invention there is provided a compensated pixel driver circuit for an organic electroluminescent device, the circuit comprising; a transistor connected so as operatively to control the current supplied to the electroluminescent device, a capacitor connected for storing an operating voltage of the transistor during a programming stage, a first switching means connected so as to establish when operative a current path through the transistor during the programming stage, a second switching means connected so as to establish when operative a current path through the transistor and the electroluminescent device during a reproduction stage, and a current sink, the first switching means being connected such that the current path during the programming stage is through the transistor to the current sink.

According to a third aspect of the present invention there is provided a method of compensating the current supply to an organic electroluminescent pixel comprising the steps of

providing a current path during a programming stage which path does not pass through the electroluminescent device and of providing a current path during a reproduction stage which path does pass through the electroluminescent device.

According to a fourth aspect of the present invention there is provided a method of compensating the current supply to an organic electroluminescent pixel comprising the steps of providing a current path during a programming stage which path connects to a current sink and of providing a current path during a reproduction stage which path passes through the electroluminescent device.

It will be noted that according to the present invention no current is applied to the electroluminescent device by the current controlling transistor during the programming stage. In accordance with the invention this can be implemented without degrading the perceived image presented by the electroluminescent device. It has the benefit of reducing the overall power consumption compared with the prior art in which the same current is supplied to the OELD during both the programming and the reproduction stage. Furthermore, the circuit can be operated from a normal supply voltage rather than requiring a high bias voltage as in the prior art. In effect, the present invention provides for separation of the programming and the reproduction current paths.

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Figure 1 shows a conventional OELD pixel driver circuit using two transistors,

Figure 2 shows a known current programmed OELD driver with threshold voltage compensation,

Figure 3 shows a compensated pixel driver circuit according to a first embodiment of the present invention,

Figure 4 shows a compensated pixel driver circuit according to a second embodiment of the present invention,

Figure 5 shows several pixels in a matrix display wherein each pixel uses the circuit of figure 4.

A compensated pixel driver circuit according to a first embodiment of the present invention is shown in figure 3. As in the circuit of figure 2, transistor T_2 operates as an analog current control to provide the driving current to the OELD. Also, the storage capacitor C_1 is connected between the gate and the source of transistor T_2. In the circuit of figure 2, a current source is operatively connected to the source of transistor T_2 by transistor T_1, during the programming stage, and current is thus applied to the OELD. In the embodiment of the present invention, transistor T_1 operatively connects transistor T_2 to a current sink during the programming stage. That is, according to the present invention, during the programming stage no current is supplied through transistor T_2 to the OELD. In the circuit of figure 3, the drain of transistor T_2 is connected to the source of transistor T_1 via the source/drain path of transistor T_3. The source of transistor T_1 is connected to the gate of transistor T_2 and the gates of transistors T_1 and T_3 are connected together. The programming voltage V_P is applied to the gates of T_1 and T_3. Transistor T_4, which is switched off during the programming stage, connects the drain of T_2 and the source of T_3 to the OELD. During the programming stage, transistor T_1 operatively connects transistor T_2 to a current sink which is tied to ground or a reference voltage.

The circuit of figure 3 operates in the programming stage with T_4 switched off and T_1 and T_3 switched on. T_3 being switched on has the effect of making T_2 act as a diode and T_1 connects this diode to the data current sink. As a result, capacitor C_1 charges (or discharges,

depending on the voltage stored during the previous frame). Capacitor C_1 charges to the gate/source voltage of transistor T_2 and thus stores the voltage (V_{GS2}, corresponding to the data current I_{DAT}) which will control the current supply to the OELD during the reproduction stage. At the end of the programming stage, T_1 and T_3 are switched off. The voltage V_{GS2} is stored on C_1 for the remainder of the frame period. As will be readily apparent from the circuit diagram and this description, in accordance with the present invention there is no requirement for a bias voltage to provide a current source. That is, the supply voltage (V_{DD}) in figure 3 is determined by T_2 and by the OELD and there is no requirement for a high voltage to power a current source. The maximum voltage required by the circuit is thus significantly less than that required by the circuit of figure 2.

At the start of the programming stage, with T_4 switched off, it is found that the OELD exhibits a parasitic capacitance which discharges through the device. The rate of charging of C_1 determines the time taken for the programming stage. In accordance with circuits embodying the present invention, the capacitance of C_1 can be relatively small and thus the charging can be very rapid. As a consequence, the period for which no current is applied to the OELD by T_2 is very short compared with the whole frame. These factors, together with the persistence of vision of the human eye means that there is no perceptible degradation of a displayed image.

The off resistance of T_3 can be important, because after C_1 has been charged and T_3 is switched off, the off resistance of T_3 can affect the voltage across C_1 for the rest of the frame period. Thus, the gate/source capacitance of T_3 should preferably be small compared with C_1.

The reproduction voltage V_R is applied to the gate of transistor T_4. At the beginning of the reproduction stage, in the circuit of figure 3, T_4 is switched on and T_1 and T_3 remain

switched off. As a result, T_2 acts as a current source with V_{GS2} biased by C_1, thus supplying current to the OELD. At the end of the reproduction stage T_4 is switched off, T_1 and T_3 remain switched off. This completes one cycle. As indicated in figure 3, the driving waveform is the same as that used with the circuit of figure 2.

Figure 4 illustrates a second embodiment according to the present invention. The circuit of figure 4 differs from that of figure 3 only in the connection of transistor T_3. In the circuit of figure 4, instead of the source of T_3 being connected to the drain of T_2 it is connected to the gate of T_2. That is, T_1 is connected to C_1 through the drain/source path of T_3. The circuit of figure 4 is preferred to that of figure 3 because T_3 is not in the current path during the programming stage. Otherwise the operation and effects of the second embodiment are the same as those of the first embodiment.

Figure 5 is a circuit diagram showing a number of pixels in an active matrix display, with each pixel implemented in accordance with the circuit of figure 4. To simplify the illustration, a monochrome display device is shown. Since the circuit is of an active matrix, pixels on the same row are addressed at the same time. Transistor T_3 is responsible for pixel addressing, so its source terminal is connected to the current data line shared by a column of pixels. Because of this the leakage current of T_3 should be kept to a minimum. This can be ensured by using a multi-gate structure for T_1.

Preferably the circuits shown in figures 3 to 5 are implemented using thin film transistor (TFT) technology, most preferably in polysilicon.

The present invention is particularly advantageous for use in small, mobile electronic products such as mobile phones, computers, CD players, DVD players and the like - although it is not limited thereto.

It will be apparent to persons skilled in the art that variations and modifications can be made to the arrangements described with respect to figure 3 to 5 without departing from the scope of the invention.

CLAIMS

1. A compensated pixel driver circuit for an organic electroluminescent device, the circuit comprising; a transistor connected so as operatively to control the current supplied to the electroluminescent device, a capacitor connected for storing an operating voltage of the transistor during a programming stage, a first switching means connected so as to establish when operative a current path through the transistor during the programming stage, and a second switching means connected so as to establish when operative a current path through the transistor and the electroluminescent device during a reproduction stage, wherein the first switching means is connected such that the current path during the programming stage does not pass through the electroluminescent device.

2. A compensated pixel driver circuit for an organic electroluminescent device, the circuit comprising; a transistor connected so as operatively to control the current supplied to the electroluminescent device, a capacitor connected for storing an operating voltage of the transistor during a programming stage, a first switching means connected so as to establish when operative a current path through the transistor during the programming stage, a second switching means connected so as to establish when operative a current path through the transistor and the electroluminescent device during a reproduction stage, and a current sink, the first switching means being connected such that the current path during the programming stage is through the transistor to the current sink.

3. A compensated pixel driver circuit as claimed in claim 1 or claim 2, further comprising a third switching means, the third switching means being connected to bias the transistor to act as a diode during the programming stage.

4. A compensated pixel driver circuit as claimed in claim 3, wherein the third switching means connects the first switching means to the source/drain current path of the transistor.

5. A compensated pixel driver circuit as claimed in claim 3, wherein the third switching means connects the first switching means to the gate of the transistor.

6. A compensated pixel driver circuit as claimed in any preceding claim, wherein the circuit is implemented with polysilicon thin film transistors.

7. A method of compensating the current supply to an organic electroluminescent pixel comprising the steps of providing a current path during a programming stage which path does not pass through the electroluminescent device and of providing a current path during a reproduction stage which path does pass through the electroluminescent device.

8. A method of compensating the current supply to an organic electroluminescent pixel comprising the steps of providing a current path during a programming stage which path connects to a current sink and of providing a current path during a reproduction stage which path passes through the electroluminescent device.

9. An organic electroluminescent display device comprising one or more compensated pixel driver circuits as claimed in any of claims 1 to 6.

ABSTRACT

A compensated pixel driver circuit for an organic electroluminescent device, the circuit comprising; a transistor connected so as operatively to control the current supplied to the electroluminescent device, a capacitor connected for storing an operating voltage of the transistor during a programming stage, a first switching means connected so as to establish when operative a current path through the transistor during the programming stage, and a second switching means connected so as to establish when operative a current path through the transistor and the electroluminescent device during a reproduction stage, wherein the first switching means is connected such that the current path during the programming stage does not pass through the electroluminescent device. No current is applied to the electroluminescent device by the current controlling transistor during the programming stage and thus the overall power consumption is reduced. Furthermore, the circuit can be operated from a normal supply voltage rather than requiring a high bias voltage. During the programming stage, the circuit uses a current sink rather than a current source.

Refer to figure 3

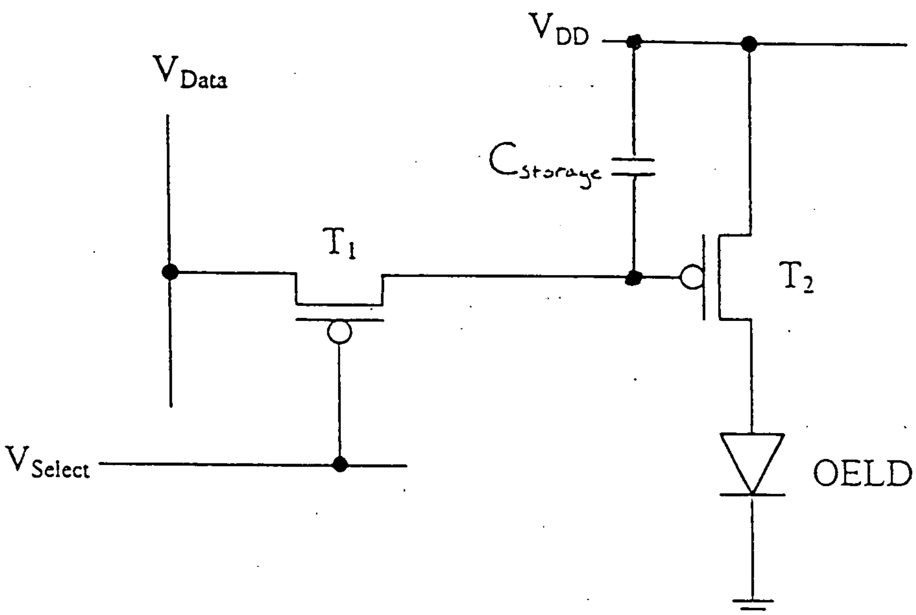

Figure 1

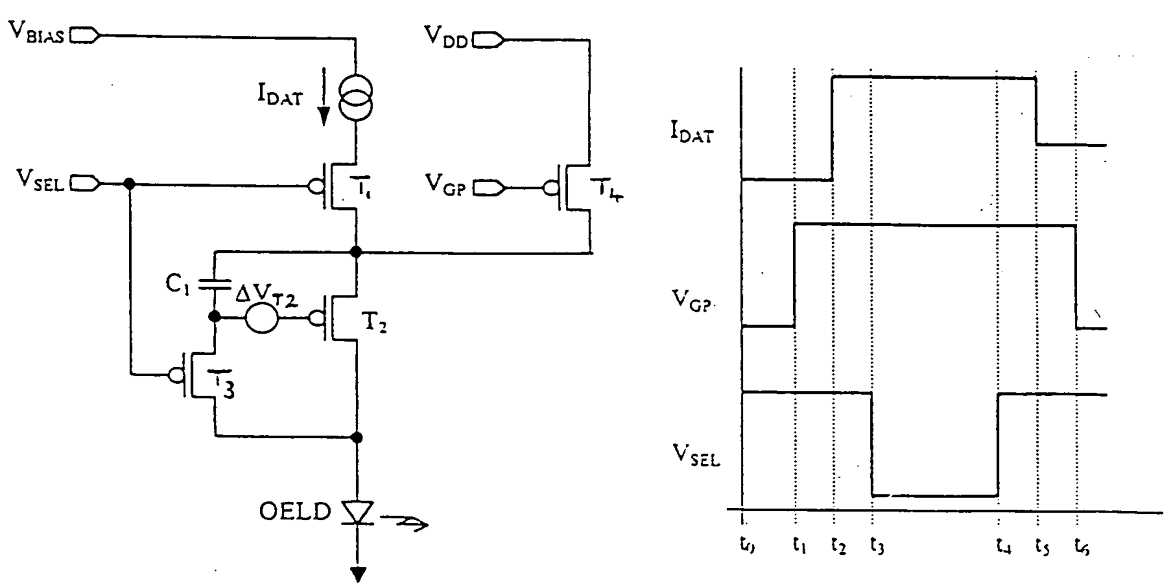

Figure 2

Figure 3

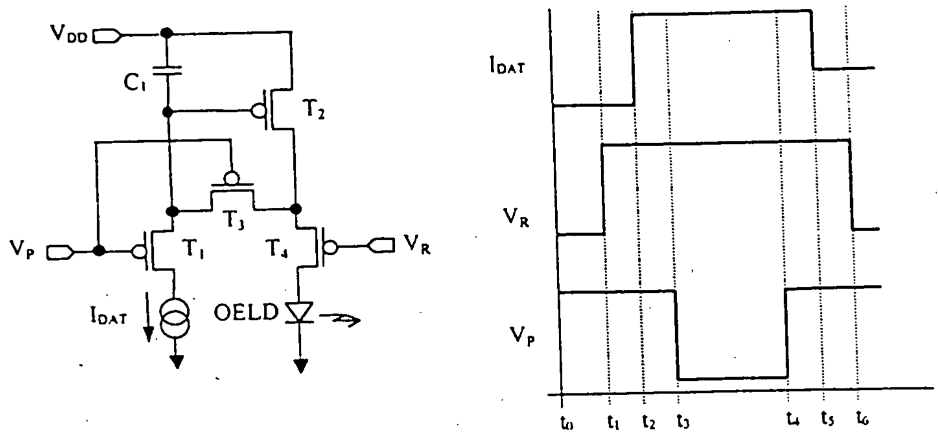

Figure 4

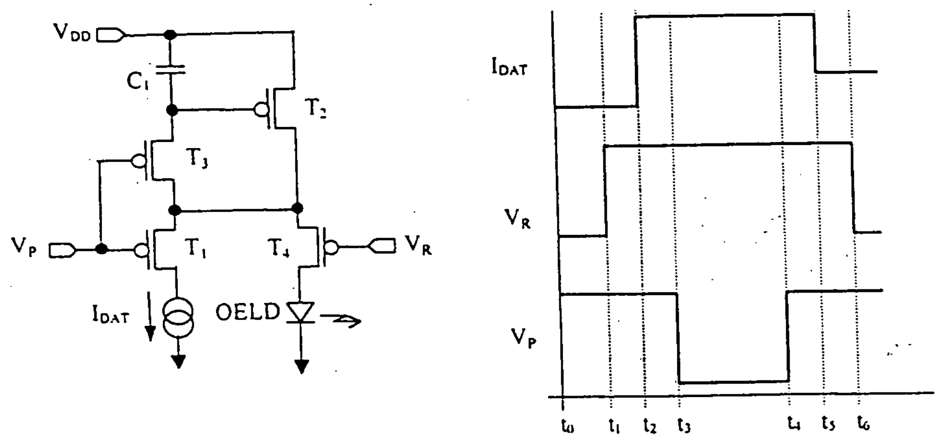

Figure 5